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UNIVERSITY OF ILLINOIS
INDIAN CORN

BY

JAMES B. McNAIR

ASSISTANT CURATOR OF ECONOMIC BOTANY



BOTANY

LEAFLET 14

FIELD MUSEUM OF NATURAL HISTORY

CHICAGO

1930

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STEPHEN C. SIMMS, DIRECTOR

FIELD MUSEUM OF NATURAL HISTORY
CHICAGO, U. S. A.

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Courtesy of Indiana Farmer's Guide

CORN IN THE SHOCK

FIELD MUSEUM OF NATURAL HISTORY

DEPARTMENT OF BOTANY

CHICAGO, 1930

LEAFLET NUMBER 14

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Indian Corn

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ORIGIN, GEOGRAPHIC DISTRIBUTION, AND VARIETIES

Origin.—When the white man reached America he found corn cultivated by the Indians in many widely separated areas. Its history before that time remains mostly a matter of conjecture. The numerous Indian myths fail to throw much light on the subject, but testify to the importance and antiquity of corn on this continent. Every Indian myth that attempts to explain the origin of agriculture deals with corn. Among the Quiche of Guatemala tradition relates that certain gods or godlike men, recently arrived in the land and much displeased with living conditions, planned to reclaim the natives from barbarism. After mature deliberation, four barbarian chiefs were sent to a distant land to get new ideas. They returned bringing with them the “ears of yellow maize and white,” which rounded out their scheme of existence and became their chief reliance for food. Another tradition of the Quiche makes corn the very breath of life. Made of earth, man was without life; but by means of maize he was converted into flesh and blood.

In an account of the South American Canari tribe, two brothers escaped the Deluge by climbing a mountain in Ecuador. When the waters subsided, they descended in search of food. Two parrots repeatedly visited the famishing men, giving them food and drink made of maize. One of the birds was captured, whereupon she miraculously changed herself into a beautiful woman. She gave the men the seed of maize, taught them its culture and uses, and ultimately became the ancestress of the Canari race.

The Navajos say that they first knew of corn when a turkey hen came flying from the direction of the morning star and shook from her feathers an ear of blue corn.

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In a tradition of one tribe of the United States, the Great Spirit comes to earth in the form of a woman and falls asleep. On waking, she arises and walks through the land, while useful plants spring up around her. At the right and left grow pumpkins and beans, and from her footprints comes maize.

Upon the return of his first expedition in 1492, Columbus reported the growing of maize in Cuba. Alvar Nuñez (Cabeza de Vaca) described it as planted by Indians in Texas in 1527. Cartier in 1534 found it in Canada, and in 1585 Hariot gave a good description of it on Roanoke Island, while in 1607 Captain John Smith wrote of it around Jamestown.

Charred corn has been found in the remains of the Mound Builders of Ohio and the Mississippi valley. Dried corn has been found in the pueblos of the southwest and in the burials of Peru. At Tarapaca, Chile, corncobs have been found buried beneath an ancient lava flow. Darwin found, on the coast of Peru, ears of corn together with eighteen species of recent seashells, imbedded in a beach which had been raised to at least eighty-five feet above the level of the sea, through movement of the earth, and this corn was identical with that taken from old Peruvian tombs. A petrified ear of corn was found at Cuzco, Peru. These findings place the cultivation of this plant in America at an early date.

By botanists corn is considered to be a highly specialized cultivated grass. For centuries it has been dependent upon man, not only for improvement, but for the continuation of life itself. As a result, corn at present exists in a form which it did not have before the coming of the Indian to the New World.

Corn is thought to have originated either in the western mountains of South America or in Mexico or Central America. Wild plants very closely related to corn have been found only in America—on the table-



Original in Field Museum

ANCIENT PERUVIAN JAR

lands and in the foothills of Central America and southeastern Mexico. One of these plants, teosinte (*Euchlaena*), hybridizes with corn. This has led those who have studied plants to believe that corn originated there.

As corn was one of the chief foods of the Indians, it is not strange that it played a decorative part in their pottery and sculpture. It also played a part in their religion and so is found the corn altar of the American Indian—the six-direction altar. Six ears of corn were placed on the ground as follows: yellow pointing north, blue pointing west, red pointing south, white pointing east, black pointing northeast, indicating above, and sweet corn pointing southwest, indicating below. Corn was used in many other ceremonies. The Aztec god of agriculture is sometimes represented with a stalk of corn in one hand. Centeotl was the Ceres of the Aztecs, their goddess of corn. The Mayas and Peruvians also made extensive use of corn in their festivities.

United States.—Corn is the outstanding crop of the United States, both as to value and acreage. In both value and area it exceeds the combined crops of wheat, oats, rye, barley, buckwheat, rice, fruits, and nuts. Since the first official registration in the United States, in 1840, of the number of agricultural products and their value, corn has led all other cereals in importance, and since 1865 there has been a noticeable increase in production in proportion to the population.

Although corn may be grown under widely varied climatic conditions, the best results are obtained only within limited areas. In the United States the best corn is grown in those parts of the country which have an average summer temperature of seventy to eighty degrees, an average night temperature of over fifty-eight degrees, a frost-free season of at least 140 days, and a yearly

rainfall of twenty-five to fifty inches, of which seven to eight inches fall in July and August. The soils best suited to corn are dark, fertile loams or silty areas, well supplied with heat and moisture, and well drained.

Thus the ideal conditions for extensive corn production occur only in a few parts of the world, and are found to the greatest extent in the United States. Within such areas the corn crop reduces the production of other cereals, especially those which must be grown during the same season of the year, to a negligible position, since corn yields about twice as much grain and, with the fodder, more than three times as much food per acre as either wheat or oats.

The United States produces about three-fourths of all the corn in the world. Although the exact temperature, soil, and moisture conditions described above are found only in certain parts of the country, corn of one or another variety is grown to a greater or less extent practically throughout the entire United States. The Mississippi valley is the great corn country, producing three-fourths of all the corn grown within our boundaries. Within the Mississippi valley are two centers of maximum corn production, one in central Illinois and the other including western Iowa and eastern Nebraska. In 1909, the area devoted to corn-growing in Illinois comprised 10,046,000 acres, or 10 per cent of all the land given to corn production throughout the country. In Iowa were 9,229,000 acres of corn; in Kansas, 8,109,000 acres; in Nebraska, 7,226,000 acres; in Missouri, 7,114,000 acres; and in Indiana, 4,901,000 acres. The corn acreage of these six states combined was 47 per cent of the total for the country, and their corn production 57 per cent of the total. As an effect of this large-scale production, a system of live stock farming has developed which makes

use of corn products. One-third of the beef cattle and about one-half of the swine in the country are raised in these states.

Although a large percentage of the total crop is produced in these middle and western portions of the country, corn is grown in almost the entire eastern part of the United States. Moreover in certain eastern regions, the acreage devoted to corn, in relation to the total acreage given to crops, is greater than anywhere else, although the actual acreage and production are small. In mountainous eastern Kentucky, where the rural population depends for its livelihood largely upon the cultivation of small fields of corn, 75 per cent of all the land under cultivation is given to this product. In Florida, southern Alabama, and Mississippi, where the land is still largely covered by forests, corn occupies 50 per cent of such land as is sown in crops.

In spite of the fact that corn is the main source of food supply in the United States, outside of the southern states very little of the corn produced is directly consumed by man. Most of the crop is used in feeding live stock, and may be said to be ultimately consumed by man in the form of beef, a pound of which represents the consumption of ten or twelve pounds of corn, or as pork, a pound of which requires, in its production, five or six pounds of corn. A large percentage of the corn produced in the Illinois and Iowa "corn belts" is shipped to near-by industrial centers, particularly Chicago, to be converted into starch, glucose, and corn meal. Some of the corn is exported in its natural state, but by far the greater portion of the crop is fed to animals, and reaches the market in that less perishable form. In the South, however, practically all the corn is consumed at home, in the various forms of "hog, hominy, and hoeecake."

Europe.—The production of corn is also carried on in Europe, in such territories as possess climatic conditions

favorable to this pursuit. Europe as a whole produces about one-fourth as much corn as the United States. The chief corn-growing countries are Hungary, Roumania, southern Russia, and Italy, all of which, as to soil, rainfall, and temperature, have similar conditions to those in the corn belts of the United States. Among these nations, Hungary leads in acreage and production. In Roumania, however, corn plays a more important part in the industrial life of the nation, since it is a main source of food and also one of the chief exports of that country. Forty per cent of the cultivated land is here sown in corn, and Roumania produces about four times as much corn, in relation to her population, as does Hungary. In Russia, most of the corn is grown in Bessarabia, not only because of the favorable climatic conditions found there, but also because of convenient location for shipping. Fifty per cent of Russian corn is shipped to other countries, while Roumania exports about 40 per cent of her total crop.

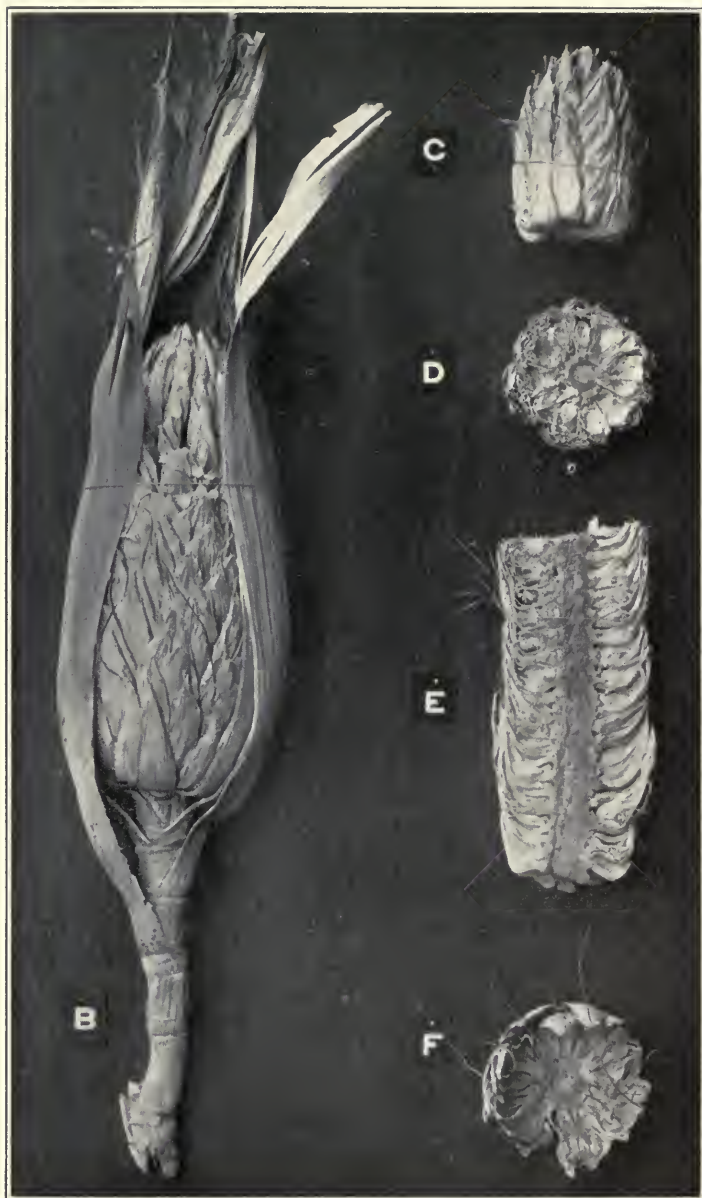
Smaller contributors to the European corn supply are Italy, where corn is grown principally in the valley of the Po, and where irrigation is often necessary; France, whose small quota is produced partly in the north and partly along the Mediterranean coast; and Spain and Portugal, where the grain can be grown only along the western and northern coasts.

Egypt and India.—The Egyptian corn crop is produced altogether by means of irrigation. The grain is planted in July, irrigated about every ten days, and harvested in October and November. India has considerable corn acreage, although it occupies only about 3 per cent of the land under cultivation. Here corn is grown in the silty soil along the Ganges, and by irrigation in the region of the Punjab. It is used principally for human food.

Mexico.—Although Mexico ranks second only to the United States in the percentage of cultivated land given to the production of corn, the yield in that country, due to primitive agricultural methods, is relatively small. Most of the corn is grown by peons on the small patches which they lease from the owners of large ranches. Irrigation is often used. A great part of the crop is used for the making of corn bread (*tortillas*) which is a favorite article of food in Mexico. The corn lands are situated in the southern part of the country, on the high tablelands, and in Yucatan. In spite of the extensive acreage, and although very little corn is exported from Mexico, the native crop is insufficient to supply the needs of the country, which regularly imports about one million bushels annually from the United States.

Canada.—In Canada, corn is grown chiefly in Ontario, under climatic conditions very similar to those found in the northern states. Most of the yield is used for silage, or fed, fresh from the field, to the farm animals.

Argentina.—Argentina ranks second to the United States in the production of corn per capita of the population. Corn-growing here is centered in Buenos Aires, Santa Fé, and Cordoba, where the mild climate and the slight variability in temperature form very favorable conditions for a large yield. Twenty-one per cent of the cultivated land in Argentina is sown in corn, and this percentage shows a tendency to increase. The corn is planted from September to December. The average summer temperature is seventy-five degrees, and the annual rainfall of thirty to forty inches contributes to the success of the industry, although the greater part of the rain comes rather late in the corn season. Because of the small population, much of the corn is exported, and the flinty type grown in this section is particularly adapted for transportation without great loss. In 1912, Argentina exported 64 per cent of her total crop.



POD CORN. EACH KERNEL IS ENCLOSED IN A HUSK

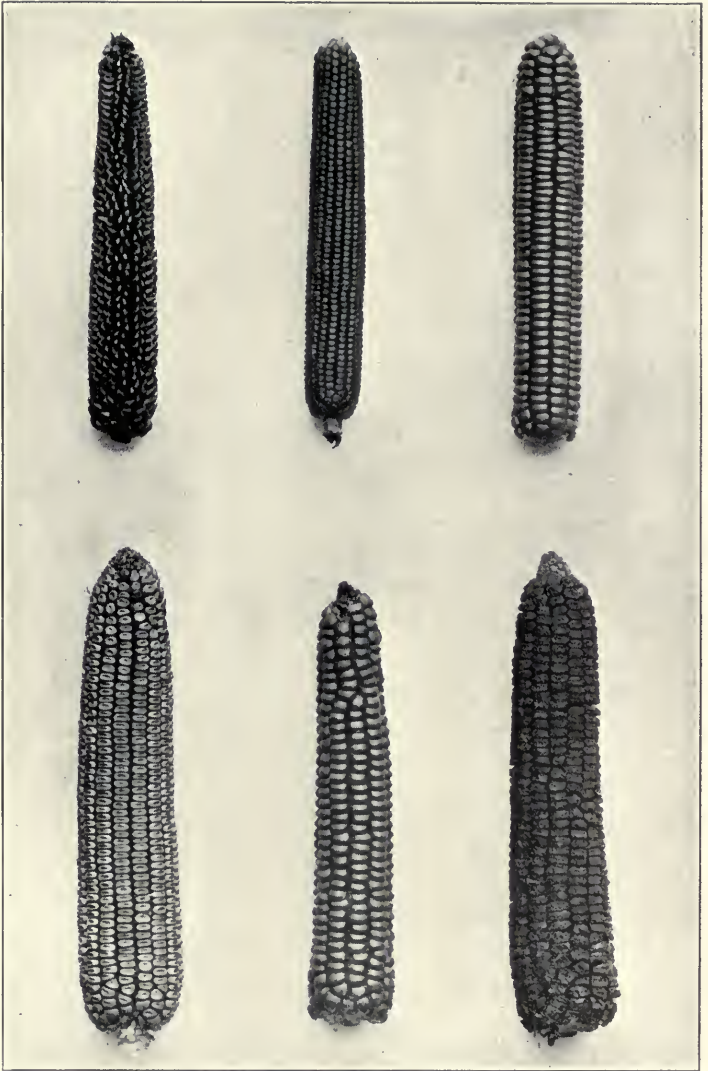
Varieties of Corn.—Almost fifty years ago Dr. Sturtevant divided Indian corn into seven groups, each of which has well-developed and lasting characteristics: pod corn (*Zea tunicata*), pop corn (*Zea everta*), flint corn (*Zea indurata*), dent corn (*Zea indentata*), soft corn (*Zea amylacea*), starchy-sweet corn (*Zea amyleasaccharata*), and sweet corn (*Zea saccharata*).

1. *Pod corn.*—In this group each kernel is inclosed in a pod or small husk and the ear thus formed is inclosed in a large husk. This type is considered by some to be the original type of corn.

2. *Pop corn.*—This species group is characterized by the large proportion of a tough, horny substance (corneous endosperm) in the starchy portion of the kernels, and by the small size both of the kernels and of the ear. The best varieties for popping have the horny substance throughout the starchy portion of the kernels. The property of popping, which is the complete eversion or turning inside out of the kernel, is caused by the explosion of the contained moisture through the application of heat.

3. *Flint corn.*—A species group readily recognized by having the starchy portion of the kernels inclosed by a coating of a horny substance, as shown in a split corn seed. This horny portion varies in thickness with the varieties. It cannot be confused with any other species except the pop corn, from which it is set apart by the larger kernel and inability to pop. In drying there is no shrinkage of the top of the grain and no dent forms.

4. *Dent corn.*—A species group recognized by the presence of horny substance at the sides of the kernel, the starchy portion extending to the summit. By the drying and shrinkage of the starchy matter the summit of the kernel is drawn in or together, and indented in various forms. In different varieties the horny substance varies in height and thickness, thus determining the character of the indented surface.



POP CORN
DENT CORN

POP CORN
SOFT CORN

FLINT CORN
SWEET CORN

5. *Soft corn*.—This species group is at once recognized by the total absence of horny material. Due to the uniformity of the shrinkage in ripening, there is usually no indentation; yet in some varieties an indentation may more or less frequently appear, but on splitting the kernel the soft corn may always be recognized.

6. *Starchy-sweet corn*.—A well-defined species group characterized by the translucent, horny appearance of the kernels, and their more or less wrinkled or shriveled condition.

7. *Sweet corn*.—A well-defined species group characterized by the translucent, horny appearance of the kernels and their more or less crinkled, wrinkled, or shriveled condition.

All seven of these groups of corn were grown by the Indians of North and South America. The certainty of sprouting is highest in pop and flint corns, lower in sweet corn, and poorest in dent corn, and the decrease in the starchy content of the kernels is in this order: pop, flint, dent, soft, starchy-sweet, and sweet.

At the present time, pop corn is extensively grown in the United States for that purpose. Almost all of the field corn in the United States is of the dent type. Flint requires a smaller number of days to mature a crop, and is consequently more used farther north and at higher elevations above sea level. It is the common field corn in New England. Dent and flint furnish all the grain of commerce and practically all the fodder and ensilage. Sweet corn forms the basis of a large canning industry in the North Atlantic and North Central states. It is less generally grown in the Southern states. Soft corn was preferred by the Indians because of its ease of grinding.

USE BY THE AMERICAN INDIAN

Stalks, Leaves, and Husks.—The Indians commonly wasted the stalks, leaves, and husks except for a limited use in mats, beds, thatching, and fuel. In Mexico and parts of South America the large, outer husks were and are still used for wrapping tamales for cooking. The thin, inner husks were used for cigarette paper. Like its near relative, sugar cane, cornstalks produce sugar. Prescott writes of the Aztecs obtaining juice from the stem, which was boiled down to a syrup or fermented and used as a drink.

Ears and Kernels.—The roasting ear was everywhere a favorite food of the Indian. Corn was eaten raw, boiled, or roasted, and the Indian invented the mixture of green corn and beans known as succotash. Parched corn was widely known and used in many ways.

Meal.—Several different methods were used by the Indians in making corn meal. In Pennsylvania, a vessel containing sand was heated. The corn was then mixed with this sand and slowly heated until the grain burst. The burst grain was then taken out and ground to a fine powder. In another method the corn was first par-boiled, the water drained off, and the grain dried. The dried kernels were roasted on a plate, ashes being mixed with them to prevent burning. The grains were stirred constantly and soon acquired a red color, at which time they were removed and well rubbed. They were then mixed with the ashes of the dried stalk of the kidney bean, a little water was added, and the mixture thoroughly pounded into meal. Among the Indians of the southwestern United States, the blue corn was used. This when rubbed in a stone mortar gave a meal of bluish-gray color. A second method used in this same section of the

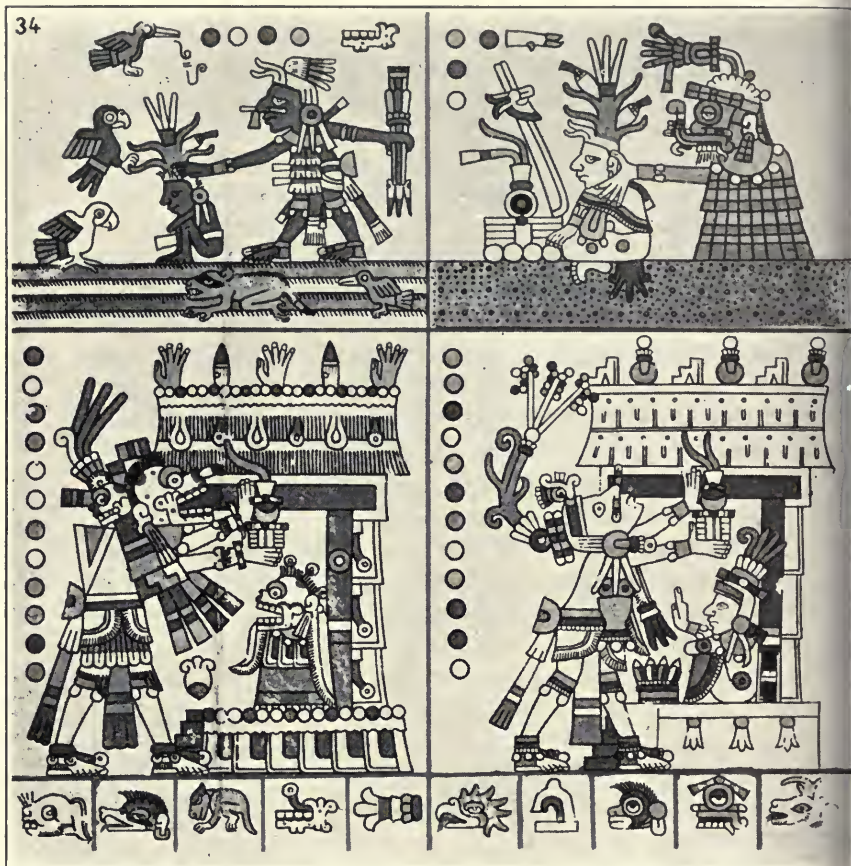
country was to cook the corn in limewater until the hard covering was removed; then the grain was pounded into white flour. This last method is used by the white man in preparing hominy.

The food use of corn meal varied in different parts of the country. The various ways of making bread were as follows: in the neighborhood of Pennsylvania the meal was kneaded with water into dough. This dough was made into round cakes about six inches in diameter and about an inch thick. They were then baked in clean wood ashes. Dough was sometimes mixed with pieces of pumpkin, beans, chestnuts, huckleberries, etc. Indians also mixed smoked eels and shellfish, chopped fine, with their corn meal in the making of bread.

The mestizas of Mexico made similar corn bread in various shapes and sizes, known as *gorditas*. In the southwestern United States and Mexico thinner cakes called *tortillas* were also made. In their manufacture a thin batter was used, dipped from a bowl by the hands and spread in a thin layer on a hot stone or plate. The mass quickly puffs up, a sign that one side is done, and it is then turned over, while the second cake is placed on to bake. Thinner cakes were made of blue starch corn by the Hopi Indians in Arizona. These thin cakes were rolled up like thin jelly rolls and were known as *piki* bread.

Pinole was corn meal cooked or mixed with sugar from the mesquite (*Prosopis juliflora* D.C.) or other source. The Central American Indians added a red coloring matter, *arnatto*, to this mixture and called it *yixte*. In Mexico such a mixture without coloring matter was cooked and wrapped in small pieces of corn husk, in the form of a necklace, for ease of transportation when traveling. These were known as *saules*.

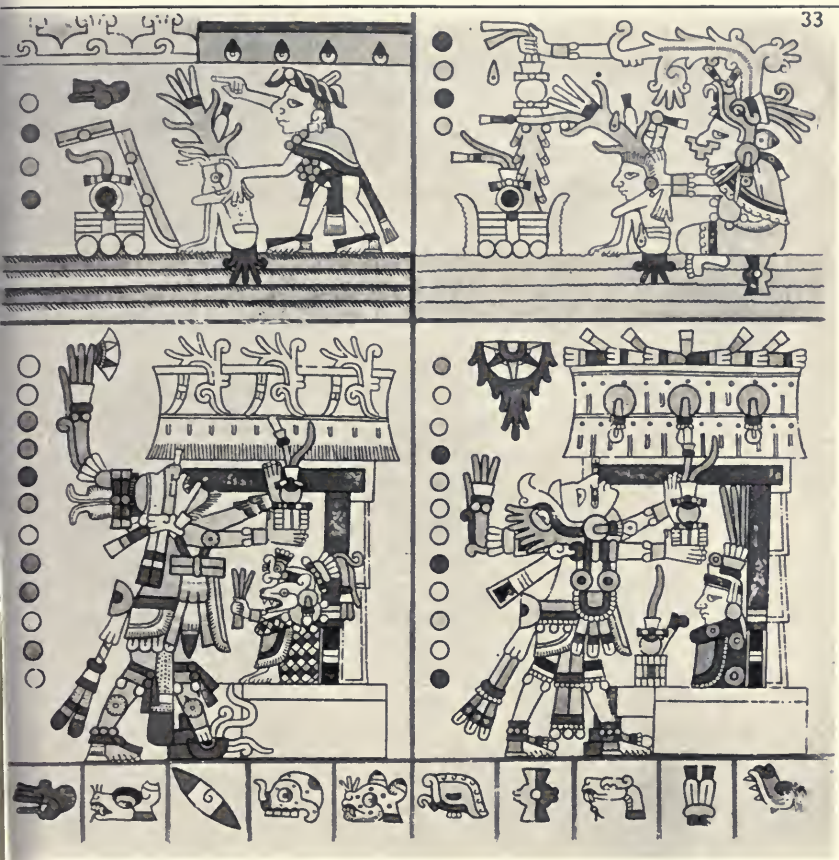
Various forms of pottage in which corn meal was the basis were familiar to the Indian. In the northeastern



Codex Fejérváry—Mayer, pp. 34-33

A PRECONQUEST MEXICAN MAIZE ALMANAC

Illustration of maize from a preconquest Indian codex from southern Mexico representing the story of the corn plant from planting to harvest. The figures read from right to left, the upper row being an allegorical series of figures representing corn in its several stages. In the first sketch of the series the corn plant is small, scantily clothed and bent (immature), while in the third sketch it is larger, fully clothed and erect (mature). Along with the corn plant are shown the rain goddess,



flower goddess, and the chief rain god. These were agricultural deities, who protected the maize crop. In the left top panel are shown various birds and rodents, which destroy the young plants. The lower row represents important Mexican divinities. According to J. Eric Thompson the time interval between each of the upper series of illustrations is 65 days. The four intervals together make 260 days, the "tonalamatl" or sacred year of the Aztecs and other Central American peoples, used in divination and for regulating times for sowing crops, etc.

section of the country the meal was boiled with fresh or dried meat (the latter pounded), dried pumpkins, beans, or chestnuts. Sometimes the mixture was sweetened with maple syrup or sugar. An appetizing dish was made by boiling well-pounded hickory nut kernels with corn. In the southwestern United States and in Mexico meal was often cooked with pieces of meat with red or green peppers or other vegetable. When this is wrapped in corn husks and boiled it is known as a *tamale*. Bread was also made from crushed, fresh, undried corn.

Beverages.—Although the Indians realized the substantial way that corn supplied some of their essential needs, yet their keenest sense of pleasure came from the drinks that it afforded. They had a great many of these. One god is said to have given the Mexicans nine excellent recipes at one visit. Probably the most commonly used fermented drink was *chicha*, which was widely known in many forms. There were many ways of preparing it. The dry, parched, or sprouted corn was either ground or masticated and then mixed with water and allowed to ferment. This was highly intoxicating.

MODERN INDUSTRIAL AND EXPERIMENTAL PRODUCTS

Like the Indian, the white man still makes meal from the corn kernels, but many other substances are also manufactured from it, such as starch, dextrine, glucose, sugar, oil, and solvents. From the cobs, pipes, xylose, sugar, and other articles can be made, while from the stalks, cane sugar, wall board, paper, artificial silk, and numerous other articles are manufactured. Let us begin with products obtained from the grain.

USE OF CORN KERNELS

In 1925 the United States produced 2,900,581,000 bushels of corn, valued at \$1,956,326,000. The firms producing corn syrup, corn sugar, corn oil, and starch valued their products at \$132,873,000. Of this amount \$95,778,000 was the value of starch and the sugars and syrups obtained from starch by the acid action.

The substances which make up the kernel vary widely in amount in accordance with breeding and cultivation; the following, however, is an average composition in parts per hundred:

	Per cent
Water.....	19.6- 10.2
Ash.....	1.2- 1.3
Oil.....	3.0- 4.5
Starch.....	60.0- 65.0
Pentosans.....	7.0- 7.5
Fiber.....	1.2- 1.5
Protein.....	8.0- 10.0
Total.....	100.0-100.0

Starch and Oil.—Starch manufacture consists of the separation of starch from the other substances of the kernel. At the end of the process of manufacture a bushel of corn yields:

	Pounds
Starch.....	32.5
Feed (20.8 lbs.)	
Gluten meal.....	6.9
Corn bran.....	5.8
Germ oil meal.....	2.0
Steep water.....	5.3
Corn oil.....	1.5
Total.....	54.0

In America the earliest processes for manufacturing starch embodied, first, the steeping in water of the grain at 77°-140° F., followed by grinding between rollers or buhr-stones, and the ground product washed in cylinder sieves. In sieving the hulls were separated from the starch. Next the starch and water mixture was run upon inclined troughs, and the starch granules deposited at the bottom of the troughs while the lighter gluten fiber ran off. The starch which had settled in the troughs was washed with a weak alkali solution to further remove gluten. Finally the starch was washed repeatedly with fresh water.

The method in general use now is known as the sulphurous acid method, first used in Europe. This was modified and improved and now consists of cleaning, steeping, grinding, sieving, tabling, washing, and drying.

In cleaning the grain, fanning mills and sieves are used to separate chaff and light particles. Electromagnets draw out any iron which would injure the grinding machinery. The clean grain is taken to large, copper-bottomed steeping vats and steeped for thirty to forty hours with water containing 0.25 per cent to 0.30 per cent sulphurous acid (SO_2). The sulphurous acid is used to prevent the formation of mildew or slime. By means of steam, the mixture is kept circulating and heated to a temperature between 115°-125° Fahrenheit. The heating is done to soften the corn. The steep water contains the salts, soluble carbohydrates, and proteins, which pass out through the covering membranes of the corn kernel. This liquid contains about 20 per cent ash, 38 per cent

protein, and 49 per cent carbohydrate and non-protein material. This water solution is concentrated by evaporation to a syrup and sprayed upon the corn gluten feed before drying.

The kernels softened by steeping are passed to Fuss mills. These mills are made up of two parallel vertical plates which rapidly revolve in opposite directions, and carry studs which project between each other. In these mills the kernel is broken, although the tough, rubbery germ at the tip of the grain passes out entire. The germ contains practically all of the oil in the grain and is extracted from the rest of the grain in germ separators. The germs are lighter in weight and are thus separated by the steaming process and ground in oil mills to express the oil. By far the most part of the oil is refined and sold as edible oil for use in salads and cooking. Unrefined corn oil is used for soap-making and for nearly all purposes to which a semi-drying oil is adapted. The oil-press cake is used for cattle feed. After the removal of the germs the remainder, which consists of starch, gluten, and fiber, is mixed with water and ground again in buhrstone mills.

The thick, liquid mass is now passed over the shakers, which are tilted bolting cloth sieves of about 200 mesh, placed in a shaking apparatus. The starch and most of the gluten are washed through the bolting cloth. The fibrous portion tumbles off the lower end of the sieve.

The liquid containing starch and gluten is passed from the shakers to inclined troughs, or tables. These wooden tables are about 100 feet long and 2 feet wide, with vertical sides. As the heavy liquid flows slowly down the tables the starch granules are deposited, while the gluten tends to pass down and off the tables. When the deposit of starch has become about ten inches thick,

the flow of starchy liquid is stopped, the gluten remaining on the surface of the starch is scraped off, and the deposited starch flushed off the table with water.

The water containing gluten which comes from the starch tables is returned, after proper treatment, to the steeping vats. The starch after it comes from the settling tables is broken up and spread out upon trays made of wood and burlap. These trays are placed in carriers or wagons, and moved through kilns or drying tunnels in which a constant current of hot air is kept up. When a wagon and its contents are thoroughly dry, they are removed from the opposite end of the tunnel.

Commercial Forms of Dried Starch.—In accordance with variations in the time and temperature of drying, different starches are formed. "Pearl starch" is dried about twenty hours at approximately 170° Fahrenheit. "Crystal starch" is formed when wet starch is placed in kilns in the form of a compact cube and drying continued for a matter of weeks. Finally the mass contracts and breaks up into distorted prisms called crystals. The size of the crystals varies with the temperature, a low heat forming larger crystals. "Powdered starch" is made from "pearl starch" by pulverizing and sifting. "Lump starch" is made by treating powdered starch with steam and high pressure. The solid cylinder of starch which results is crushed and screened to size.

Various Uses of Starch and Starch Modifications.—Starch when treated with acids or alkalis forms purified starches, soluble starches, thin-boiling starches, and alkaline thick-boiling starches. Dextrines are made by roasting slightly acidified starch under various degrees of temperature and pressure. Several forms of starch are used in the textile industries for stiffening and finishing warp and cop yarns; as a filler, finisher, and size in paper-making; for food uses in the manufacture of baking

powders, pie fillings, pastes, sauces, jellies, and puddings; for laundry purposes; for dusting molds in foundries; and in the production of asbestos products, oilcloth, linoleum, explosives, paints, soaps, adhesives, coal briquettes, etc. Several varieties of dextrines are made use of in textile industries for sizing and stiffening the fiber, finishing the fabric, thickening the colors in calico and other printing, dressing leather, and in pastes, gums, glues, ink, fireworks, etc.

Solvents.—Besides the above use for starch, there is another in which starch is transformed into solvents or lacquers used to a great extent in the automobile industry. Corn although used to its greatest extent as a feed for animals and a food for man is not always fit for these purposes, as large quantities become spoiled. Previous to 1918, this low-grade corn was used to a large extent in the making of whiskey and starch and its by-products. But now the solvent industry has become one of its largest users.

Besides low-grade corn unfit for consumption other carbohydrates may be used as raw materials for this process. The corn is first screened to remove dirt and other fine matter, next passed through a magnetic separator to remove pieces of iron and steel, and finally ground in roller mills. The product from the roller mills is screened to separate the flour, and the larger particles are returned to the mill for further grinding. The membrane covering the kernels (bran) after separation from the flour is sold for feed. Generally whole corn is used in this process, but part of the corn may be degermed and only the starch used. All the corn is not degermed because the germs contain protein, and too large a reduction in the amount of protein in the process would be objectionable, for protein is necessary to the growth of the micro-organisms

used in the process. As much of the corn is degermed as possible, however, as the oil obtained from the germs more than pays for the cost of separating it.

A great amount of corn meal is carried from the storage bins to the mashing vats. In the vats warm water is added and when the mixture has been made up to its proper consistency, the material is dropped into cookers. In the cookers, which are inclosed autoclaves, the material is cooked for two hours by live steam under pressure. This cooking is done to sterilize the material as well as to bring it to the proper condition for fermentation. At the end of the heating period the charge is blown by its own pressure from the cookers to the fermenters. On its way to the fermenters the sterile starch solution is cooled to below blood heat. At this point the mixture has about the consistency of ordinary flour paste. It is of interest to note that no malt is used and that the solution to be fermented contains starch and not sugar. Precautions are taken at the pipe lines, and storage vessels and fermenters are protected from contamination by any wild yeast and fungi.

The micro-organism used in the process to transform starch into solvents (butanol, acetone, and alcohol) is a bacterium, *Clostridium acetobutyricum* (Weizmann). A pure culture of this micro-organism is obtained, and before addition to the sterilized starch solution a large quantity of the micro-organism is obtained, so that it will outgrow any foreign micro-organism that might be present to contaminate the mixture.

The clostridium changes 3 pounds of starch into 1 pound of mixed solvents in the form of a $2\frac{1}{2}$ per cent solution. During this change a gaseous mixture of 45 per cent hydrogen and 55 per cent carbon dioxide is given off. The liquid solvent mixture obtained as a $2\frac{1}{2}$ per cent solution consists of approximately 60 per cent butanol,

30 per cent acetone, and 10 per cent ethanol. After fermentation the solution passes to a large reservoir from which it is pumped to stills. This is the only point in the process where mash is pumped. These stills are columns eight feet in diameter and fifty-four feet high. The $2\frac{1}{2}$ per cent solvent mixture in passing through the stills is changed to a 50 per cent mixture. The resultant mixture is later fractionated in other stills into its three principal constituents, namely butanol, acetone, and ethanol. This separation is made easier because of the fact that butanol and water form two layers.

By-products are formed at three stages in the process. The first by-product is the bran or outer membrane of the kernel which is separated from the corn in the grinding process. The second by-product is the mixture of the hydrogen and carbon dioxide gases formed in the fermentation, and the third by-product is the waste from the stills. The bran, as already said, is sold for feed. The profitable disposition of the hydrogen and carbon dioxide gases and the still waste are more complex problems. The hydrogen is readily separated from the carbon dioxide by the solution of the carbon dioxide in water. The hydrogen may find its commercial use in the manufacture of ammonia. By passing the mixed hydrogen and carbon dioxide gases over heated carbon, a mixture of carbon monoxide and hydrogen is secured, which might serve for the manufacture of methanol. The waste from the stills contains about 1 per cent solid matter. These particles of solid matter may be removed readily by passing the waste through a fine screen. The particles collected in this way are nutritious and may be sold as feed.

USE OF CORNCOBS

The corn crop estimates of the United States government are based on bushels of shelled corn. For each bushel of shelled corn fourteen pounds of cobs have been

harvested. For the four years 1923-27, an average of 2,676,200,000 bushels of corn has been brought to market annually. Such an amount would be obtained from a yearly harvest of 19,000,000 tons of corncobs. Of this number approximately 1,444,800 tons of cobs were received at the grain elevators scattered throughout the corn belt. From these grain elevators the cobs could readily be obtained for manufacturing purposes.

Tobacco Pipes.—Corncobs are perhaps best known in the form of tobacco pipes called Kentucky or Missouri “meerschaums.” However, they use but a very small fraction of the annual product of corncobs.

Fuel.—At the present time corncobs have their greatest use as fuel. In the western states the fuel supply used to be uncertain and many cobs, as well as full ears of corn, were used as fuel. In fuel value three tons of corncobs equal one ton of hard coal. In France, the cobs, soaked in resinous matter (sixty parts melted resin and forty parts tar) were formerly used as fire lighters and were bought at from twelve to twenty francs.

Potash.—Corncobs contain a large amount of potash, in fact more potash than any other mineral constituent. Mills which shell corn frequently use cobs as fuel. A mill shelling 5,000 bushels an hour has 7,000 pounds of cobs per hour. The ashes in the mill are collected for the extraction of potash. One thousand cobs yield 7.62 pounds of potassium carbonate, or in a factory of the above capacity, 535 pounds per ten-hour day. Experiments have been carried on with the use of impure corncob ashes as a water softener.

Meat-smoking.—Meat-smoking and bee-smoking have been carried on successfully by the use of corncobs.

Insulating Material.—During the last few years a product has appeared in the Chicago markets made out of corncobs to be used for insulating houses already con-

structed. It is called kalkite, with the accredited composition of nineteen parts corncobs, twelve parts gypsum, and two parts waste paper and chemicals. Corncobs, bought at grain elevators for a dollar a ton loaded on the cars, are ground up to the fineness of granulated cork. The gypsum acts as a binder, and together with the other chemicals makes a product vermin-proof and practically fireproof. Houses are insulated with this material without disturbing the contents. Holes are bored in the plate between the studs in the attic, and the wall space is filled with a mixture of kalkite and 10 per cent water. The space between the floors is filled with the material in similar manner. On a floor the product weighs about $4\frac{1}{2}$ pounds per square foot. Kalkite has been tested by the United States Bureau of Standards and shows a heat conductivity of forty British thermal units per hour, per square foot, per one inch in thickness, per one degree Fahrenheit change in temperature.

Miscellaneous Uses.—Corncob flour has been substituted for wood flour in many ways, for example as a basis for punk and incense and in curing concrete floors in place of sawdust. Corncob flour has also been substituted for bran in removing oil from tin plate in the tin-plating industry. Corncobs heated with water and steam under pressure produce a powerful adhesive. When corncobs are subjected to destructive distillation, products similar to those obtained from wood are secured, that is, charcoal, acetic acid, wood alcohol, tar, illuminating gas, and alcohol. The charcoal has been found to be an excellent medicinal charcoal. Under suitable treatment it forms a very good decolorizer.

Xylose or Wood Sugar.—This sugar may be obtained from corncobs by boiling them with dilute sulphuric acid. It is found occurring naturally in the nucleoproteids of plants and animals, and is perhaps the only

sugar made up of five carbon atoms to be found in animals. It is about one-half as sweet as cane sugar, whereas glucose from starch is three-fourths as sweet as cane sugar. Xylose does not ferment with yeast and therefore is probably indigestible and without food value to man. It may, however, be of use as a sweetener for the food of persons suffering from diabetes. Xylose may be obtained not only from corncobs but also by the action of dilute sulphuric acid on bran, straw, and various other vegetable products.

Furfural.—Furfuraldehyde or furfural is formed when xylose is distilled with hydrochloric (muriatic) acid or with dilute sulphuric acid (vitriol). It is more practical to obtain furfural by distilling a mixture of dilute hydrochloric acid and ground corncobs. The distilling vapor is condensed to a mixture of furfural and water which may be fractionated to produce almost pure furfural. Furfural, like formaldehyde, will form a hard resin similar to bakelite. The resin formed can be used in varnishes or when added to a suitable filler such as wood or corncob flour as a molding resin. Resin may be formed from furfural by the addition of phenol (carbolic acid), or may be made directly in the ground cobs by the addition of hydrochloric acid and phenol.

Furfural acts as a preservative, and has been used in veterinary embalming fluid and for other purposes. It is also a solvent for nitro-cellulose and cellulose acetate. As a solvent it removes varnish readily. During the war it was used in "dope" for airplane wings. The Chemical Department of the Iowa State College has made a number of dyes and anaesthetics from furfural. It has been used as an accelerator in rubber curing. It can also be used as a fuel to replace gasoline, although its expense makes it impractical for present use for that purpose. When added to gasoline it forms an anti-knock motor fuel.

The yield of furfural from corncobs is about 10 per cent of their weight. An equivalent amount can also be produced from oat hulls and other material. This is about half the laboratory or theoretical yield. Cottonseed bran yields 22 per cent, which is double the amount from corncobs. Because oat hulls and cottonseed hulls are produced over a large period each year, they are more desirable as a source of furfural than corncobs, which are only at present available in the elevators from November to May.

THE USE OF STALKS

Syrup.—Most of the different plants of the grass family have hollow stems, but there are three notable exceptions: sorghum, sugar cane, and corn. All three contain cane sugar. The Aztecs in Mexico made use of the corn plant for sugar, in the same manner as sugar cane is now used. An interesting review of the trade in corn sugar in Colonial days is given by Collier in his book on sorghum sugar. Work carried on at the Minnesota Agricultural Experiment Station resulted in the following: a cannery which cans only corn has available approximately 500 acres of stalks or 4,000 tons per year, which could produce 1,100 gallons of syrup per day, or 38,000 during a season. In the Minnesota experiments five varieties of sweet corn and two of field corn were used. When the corn is ripe enough to can, the juice of the stalks contains 9–11 per cent cane sugar. If the stalks stand in the field twenty days after the removal of the ears, the amount of sugar in the stalk increases to 13–17 per cent. The proper stage for syrup-making is during the time of maximum amount of sugar in the juice, not only because of the yield but because of the quality of the juice. Cornstalk syrup may be manufactured by nearly the same process as sorghum syrup. The controlled defecation, filtration, and vacuum evaporation may be used. Cornstalk syrup is clear, reddish amber in

color, with a pleasant flavor. As produced, it is not a table syrup but an excellent cooking syrup considered equal to the best grades of sorghum and cane molasses. As estimated by the Minnesota Experiment Station, the commercial manufacture of cornstalk syrup is not very profitable. They assume that three dollars per ton of fresh stalks would be satisfactory to the grower. This would amount to eighteen or twenty-one cents per gallon of syrup. Actual cost of manufacture is considered as thirty cents. The total cost is consequently about fifty cents per gallon, and could sell wholesale at about sixty-eight cents to compete successfully with the best grade of sorghum syrup. If the manufacturing plant cost \$60,000 the returns at sixty-eight cents per gallon for syrup would be about 11 per cent. These figures allow for the utilization of bagasse and leaves.

Wall Board.—The usual height of cornstalks in the Corn Belt is from six to ten feet, although the plant has been known to grow anywhere from eighteen inches to twenty-four feet high. The stalk consists of a hard outer shell inclosing a center of soft pith. This outer shell is made up of many bundles of long, thin fibers and microscopic tubes called fibrovascular bundles. Some fibrovascular bundles also appear in the pith. The leaves on the cornstalk are attached every eight or ten inches along the stem. At these points of attachment the fibrovascular bundles going to the leaves from the stem form hard, dense portions, known as nodes. The soft pith is composed of flat, non-fibrous cells.

As tall office buildings have frameworks of steel, so cornstalks have frameworks of cellulose fibers. Consequently cellulose makes up 45 per cent of their total weight. It is interesting to note that various woods contain 48–62 per cent of cellulose. Another constituent of cornstalks is lignin, to the extent of 31 per cent, which

equals the average content of lignin in woods. Characteristic constituents of cornstalks are their pentosans, which make up over 27 per cent of their weight, while in common woods the percentage varies between 7 and 25. The chemical difference between the hard portion of the stalk and the soft pith apparently is slight, while their physical characters differ very greatly. Corn leaves are lower in cellulose than the stalks or husks. The cobs also have a lower cellulose content, but are higher in pentosans. A chemical analysis of cornstalks and cobs shows them to be not greatly different from wood.

Wall board can be made from cornstalks by the use of machinery, water, heat, and pressure. By the use of a paper beater or rod mill the long, strong fibrovascular bundles are torn apart by shredding and beating in water. The beating is continued until the fibers are of the proper length. In so doing they have absorbed a large quantity of water and become slightly sticky on the surface. When pressed together and dried, they form board. Cooking under pressure increases the property of sticking together. The use of such board as building material has rapidly developed. A short time ago wall board and insulating board were used only in temporary partitions or in cheap repair work, and were considered suitable only for such uses. Today, however, a great deal is used in the making of houses of the better sort. The heat and sound insulating properties of such materials are due to the minute air pockets between the fibers, which efficiently interfere with the circulation of air and heat and the transmission of sound. Other, similar boards are made from wood, wheat straw, flax straw, sugar cane waste, licorice root waste, cork, etc. These boards when used in buildings form a substitute for lath and plaster or serve as a plaster base or as sheathing either beneath wooden siding or under stone or brick veneer.

A hard, dense form of board has been made with the joint application of heat and pressure in a special type of hydraulic press. Such boards resemble a very hard, grainless wood, suitable for use as panels. Another form of useful material is made by impregnating the felted material with synthetic resin.

Paper.—Besides wall board, cornstalks can be made into paper. Experiments have been conducted by the United States government in cooperation with Iowa State College, where the entire cornstalks have been made into paper without any attempt at separation of the parts. Good paper can be made by various processes. Excellent paper of the quality used in books and writing paper may be produced by the "soda process." This method involves cooking the stalks in caustic soda or lye. Paper made by a somewhat modified "soda process," called the Dörner process, now appears for sale. The Kraft method furnishes a good brown wrapping paper. A cheap mechanical pulp paper suitable for newspapers is being developed.

Artificial Silk.—Further refinement of paper pulp results in a substance known as alpha cellulose. Alpha cellulose is the basic material for rayon, or artificial silk. The commercial output of rayon at present comes from wood and cotton. Experimental work in a rayon factory showed that high-grade rayon can be made from cornstalk pulp by any of the three methods now in common use.

Statistics on Cornstalk Production.—The United States produced annually an average of 2,676,220,000 bushels of corn for the four years 1923 to 1927, inclusive. Assuming that 84 per cent of the crop was harvested for grain, and that the stover-grain ratio was 150, the amount of stover produced annually would be 94,000,000 tons. If one-third of the weight of stover consisted of water at the time it was harvested, there would be not less than

62,000,000 tons of bone-dry material for use in wall board, paper, or artificial silk manufacture. One ton of cornstalks is said to make 2,000 square feet of wall board. The yearly production of cornstalks in Iowa available for manufacture is estimated as 10,000,000 moisture-free tons. Iowa could therefore make each year from unused cornstalks 20,000,000,000 square feet of wall board.

The average yield of stalks per acre is calculated at a minimum of one and one-half tons. In Iowa one-third of the land is considered as planted in corn. Therefore a manufacturing plant in operation 300 days a year could obtain eighty tons of stalks a day from within a five-mile radius or 335 tons a day within a ten-mile radius. In that part of Iowa where 60 per cent of the land is planted in corn, a radius of five miles will give 150 tons of stalks a day and ten miles will yield 600 tons of stalks a day. According to these estimates, the length of haul to supply even a fairly large factory would be short.

To determine the proper method of harvesting cornstalks, the Agricultural Engineering Department of Iowa State College carried on an extensive study. As a result, a machine has been made which both cuts and bales the stalks as it goes over the field. The machine is a combination of a mower, a hay loader, and a baler, made into one, and pulled by a tractor. Two men are needed to operate the machine. Cost of operation is considered to be \$2.40 per ton.

On the farm the immature, green stalks together with the grain are used in making silage, a very good food for farm animals. The mature, fully grown stalks from which the ripe ears of corn have been gathered have very little food value, but do have a commercial value in the manufacture of wall board and paper. At the present time they are for the most part ploughed under for fertilizer or burned to clear the field for the spring ploughing.

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An exhibit of corn and products derived from corn kernels such as oil, starch, glucose, and alcohol is to be found in Hall 25 in Field Museum. In Hall 28 will be found the various industrial products derived from cornstalks, cobs, kernels, and husks such as wall board, paper, and solvents.

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